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SILTING OF STOCK PONDS IN LAND UTILIZATION PROJECT AREA

SD-LU-2 PIERRE, SOUTH DAKOTA

By

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Geologist

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Sedimentation Section

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INTRODUCTION

This report contains the results of an investigation of the effects of silting on stock ponds and reservoirs in the Land Utilization Project (SD-LU-2) of the Soil Conservation Service, located near Pierre, South Dakota. The study was made at the request of Soil Conservation Service regional officials at Lincoln, Nebraska, to furnish a basis for estimating maintenance costs on 43 Government-owned reservoirs and stock ponds. These maintenance costs are included in the grazing fees chargeable to the local grazing association and other users of these lands. The field investigation, made in June 1945, involved reconnaissance sedimentation surveys of 18 representative ponds and reservoirs.

HISTORICAL INFORMATION

Development of Project Area

The SD-LU-2 Project comprises a gross area of 209,221 acres, of which a total of 115,042 acres were acquired by the Government. The project, located in parts of Jones, Lyman and Stanley Counties in south central South Dakota (Fig.6), was established October 4, 1934 as part of the Sub-marginal Land Purchase Program of the Federal Emergency Relief Administration by the Land Policy Section of the Agricultural Adjustment Administration. Administration of the project was transferred to the Resettlement Administration in June 1935 and later to the Farm Security Administration and the Bureau of Agricultural Economics. Administration of the project was transferred to the Soil Conservation Service on November 1, 1938.

One of the major reasons for the establishment of the project was the excessive selenium content of the soil which causes selenium poisoning to humans and livestock who eat crops grown on this land. Also, precipitation is limited and varies markedly from year to year so that cash crop farming in this area is

hazardous. The acquisition, retirement from cultivation, and reseeding to grass of the most toxic areas, coupled with a program of experimentation and restricted grazing use, were considered necessary to effect desirable social and land use adjustments in the area.

The South Dakota State Experiment Station is carrying on experimental work in the area on the toxic soil problem. In the meantime, controlled grazing of project lands in large units seems to be the most feasible method of using the land to minimize selenium trouble and to control soil erosion.

To facilitate the proper handling of grazing, abandoned farmsteads were obliterated and large grazing areas, or community pastures, were developed by refencing. Each area became a complete unit in itself insofar as its use was concerned. Erosion control was established by means of planting, listing and check dam installation. Impounding dams were used to develop stock water supply on each grazing unit.

The Soil Conservation Service took over the project after most of the development work had been completed so that it has been concerned mainly with the maintenance of existing developments.

Ponds and Reservoirs

Underground water supplies are not abundant in this section of South Dakota. The permanent water table lies so far below the surface that well drilling is non economical. The provision of a suitable livestock water supply for the grazing units, therefore, rested mainly on the construction of reservoirs to impound surface runoff.

Two types of dams, job numbers 226 and 243, were constructed according to standard specifications. Job number 226 consisted of larger reservoirs which provide, when full, a sufficient supply of water for at least two drought years. These dams were located so that livestock seldom should be required to travel a distance in excess of two miles to secure water. A total of 33 reservoirs were constructed under job number 226. Of these, 32 are still in operation, one having been washed out. Capacities of the reservoirs varied from 9 acre-feet for the smallest to 217 acre-feet for the largest. Surface areas ranged from 2 to 33 acres.

Small stock water ponds, job number 243, were constructed to supplement the main reservoir system so that in each grazing unit a better utilization of grass could be secured because of a more even distribution of livestock. These ponds are relatively shallow and are similar to dams built by farmers in this area, but generally were better constructed. The ponds were designed to supply water during the entire grazing season, although under

drought conditions they were expected to go dry. Fourteen ponds of this type were originally proposed. Twelve were constructed, but one was later abandoned leaving a total of 11 dams still in operation. Ponds constructed under job number 243 ranged in capacity from 2.6 to 13 acre-feet with areas of less than 1 acre to 4 acres.

Locations of the 43 existing dams are shown in Fig. 6. All the dams are of earth-fill construction. Materials used for their construction were obtained from the reservoir basin so that the borrow pits increased the normal capacities of the basins. All of the dams have vegetated flood spillways. Trickle tubes have been installed in a number of them. Wave erosion of the upstream faces of the dams has been retarded by the installation of floats in front of the dams and by woven wire and hay or willow riprap on the faces of the dams. The dams were fenced off to prevent damage by stock.

GENERAL DESCRIPTION OF AREA

Geography

The project area covers parts or all of Townships 1, 2 and 3 North, Range 31 East and Townships 106, 107, 108 and 109 North, Ranges 77, 78 and 79 West. It is located in the deeply entrenched, unglaciated Missouri plateau section of the northern Great Plains physiographic province. Drainage, which is well developed, is to the Missouri River over most of the area except in the northwestern portion where drainage is to the Bad River. The northern boundary of the project area is 6 miles south of Pierre, S. Dak.

Topography

The topography of the area consists of rounded hills and ridges. In general, a 3 to 4-mile belt of level to gently rolling topography extends east and west across the north-central portion of the project area. North and south of this belt the relief becomes progressively greater. Very rough topography is found in the extreme northern part of the area, in the vicinity of the Missouri and Bad River breaks.

Individual watersheds above the ponds and reservoirs present a considerable diversity of topography, ranging from very gently rolling to hilly and rough. Channelization is pronounced in the steeper watersheds and in some instances is progressing rapidly headward. In the long, wide, gently sloping valleys, channelization is not prevalent and in some of these, especially in the upper reaches, the location of flows can be recognized only by the increased density of vegetation. An analysis of drainage density, e.g. the length of channelization per unit of drainage area, for the 18 watersheds above the ponds and reservoirs

surveyed, showed a range from 3 feet per acre for gently rolling topography to 89 feet per acre for hilly to rough topography.

Geology and Soils

The geology of the project area is relatively simple. Exposed outcrops are predominantly dark gray and black Pierre shale of Upper Cretaceous age. Deep erosion has exposed beds of chalky limestone or calcareous clay. Several buttes are located within the area.

The soils are unusually uniform. They consist of clays or clay loams of residual origin derived by weathering from Pierre shale. They vary in color from light brown, brown, or olive brown when dry to black when wet. When dry they are compact and refractory but become very sticky when wet. The soils grade into a substratum of partially weathered shale. The soil mantle is usually fairly thick but in areas where erosion has progressed more rapidly than soil formation, especially in the northern extremities of the area, the soil mantle is very thin or entirely absent.

Land Use and Cover

Data are not available on the land use of the area prior to the date that the project was established. A detailed range survey made in 1941 by the Soil Conservation Service revealed that range land then occupied 81 percent of the total project area. Western wheat grass, buffalo grass and blue grama are the dominant species of natural forage grasses. Most of the sloping land is, at present, well grassed. Cultivation is confined generally to the level or gently rolling upland. Very little of the soil eroded from cultivated uplands is carried down to the ponds or reservoirs; it is deposited in grassed areas which almost always separate cultivated land areas from the main channels of the watersheds. Table 1 gives the land use acreages and percentages as determined by the 1941 range survey.

Table 1.--Land Use on SD-LU-2 Project, Pierre, S.Dak.,1941

	Acres	Percent
Range land	169,373	81.0
Abandoned land	14,452	6.9
Cultivated land	24,751	11.8
Other (farmsteads, etc.)	645	0.3
Total	209,221	100.0

HYDROLOGY

Precipitation

The mean annual precipitation at Pierre, S. Dak., for the 53-year period, 1891-1944 was 16.20 inches. The minimum annual precipitation for this period, which occurred in 1939, was 8.85 inches or 54.6 percent of normal. The highest annual precipitation occurred in 1944 when 23.46 inches was recorded. Figure 1 shows that there have been two prolonged periods of drought at Pierre since 1891. The first, occurring from 1909 to 1913, produced an accumulated precipitation deficiency of 19.63 inches. The second, and by far the most severe, occurred between 1933 and 1940. The total deficiency during this 8-year period amounted to 32.27 inches.

The highest mean monthly rainfall during the year occurs in June (see Fig. 2). About 88 percent of the total annual precipitation falls during the grazing season, April to November, inclusive.

METHOD OF SURVEYS

A thorough study was made of old project files, maps and aerial photographs to select representative ponds and reservoirs for survey. Factors considered in the selection included land use, size of drainage area, topography and absence of other ponds in the watershed which would influence the sedimentation record. In all, 18 ponds were selected as being suitable for sedimentation surveys. Distribution of these ponds is shown in Figure 6.

The shoreline was remapped with plane table and telescopic allidade on all but two of the ponds and reservoirs selected for survey. The original capacities and sediment volumes were determined by the range method.[1] From 2 to 8 ranges were laid out on each reservoir depending on its size and shape. A total of 502 sediment-thickness observations were made along 73 ranges on the 18 ponds and reservoirs. Direct measurements of sediment and water depths were made at regular intervals along the ranges with a sounding pole consisting of a 15-foot ash pump rod marked at 0.5 foot intervals.

Water and sediment depths for each range were plotted on cross-sectional paper and the respective water and sediment areas in the cross-section were determined by planimetering. Surface areas between ranges were determined by planimetering directly from the plane table sheets. The volume of water and the volume of sediment was determined by the formula:

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[1] See: Eakin, H.M. Silting of Reservoirs. U.S.Dept.Agr.,Tech. Bul.524, revised by C.B.Brown, 168pp.,illus. Washington, U.S.Gov't print.off.,1939.

$$V = \frac{A'}{3}\left(\frac{E_1 + E_2}{W_1 + W_2}\right) + \frac{A}{3}\left(\frac{E_1}{W_1} + \frac{E_2}{W_2}\right) + \frac{h_3E_3 + h_4E_4 - - -}{130{,}680}$$

where: V = Original capacity or sediment volume, in acre-feet.

A' = The quadrilateral area in acres formed by connecting points of range intersection with creast contour between ranges.

A = The lake area of the segment, in acres.

E = The cross-sectional area, in square feet

W = Length of bounding range at crest elevation, in feet.

h = The perpendicular distance from the range on a tributary to the junction of the tributary with the main stream or to a point where the thalweg of the tributary intersects the downstream range.

Character and Distribution of Sediment

Contact between the lake deposits and the underlying original bottom materials was easily recognized with the sounding pole. Bottom materials were extremely compact and could not be penetrated with the sounding pole more than about one inch, even with considerable force applied to the pole. The lake sediment was fairly compact, enough so that the surface could be identified accurately within an inch. The sounding pole could be forced easily through the lake sediment to the original bottom, however, with moderate pressure. Determination of silt thicknesses in shallow areas near the shores was difficult or impossible because silt and soil were intermixed by trampling of cattle. However, since these areas constitute only a small part of the total areas of the ponds this did not cause much loss in accuracy of the surveys as a whole.

Except for degree of compaction the lake sediment does not differ greatly from the original soil. As the Pierre soils in the project area contain little or no sand, the sediments derived from them are also free of sand. No grading of deposits even in areas normally containing deltas is apparent to the eye. The sediment contains a mixture of silt and clay which is deposited more or less uniformally over the reservoir bottom. Maximum silt thicknesses are usually found in the deeper sections of the reservoirs, especially in the borrow pit areas. Sediment thicknesses seem to be more directly related to water depths than to any other single factor. Sediment varies in color from gray to black and, like the original soil, is extremely plastic when wet.

Capacity Losses

Depletion of storage capacities is shown in table 2. Total capacity losses vary from 8.12 percent in reservoir 226-13 to 42.77 percent in stock pond 243-2. The mean annual loss of storage varies from 0.93 percent in 226-13 to 5.56 percent in 243-2.

Sources of Sediment

No detailed studies were made of sediment source areas, but general inspection of the watersheds above the ponds and reservoirs surveyed indicated that the bulk of sediment is derived from sheet erosion.

Channel erosion is serious in only a few watersheds and where such erosion was evident at the time the reservoirs were built attempts were made to control it by construction of check dams. A total of 41 check dams were built in the project area. A variety of types were used depending in many instances on the local material available. On larger channels concrete rubble masonry dams were constructed but cutting has taken place around the ends of a number of these structures allowing channel erosion to continue. Most serious channel erosion occurs in the watershed above 226-11 where 13 check dams of various types have been built. Inspection of several of the check dams which have washed out in this watershed indicate that they had been successful in halting headward erosion up to the time that they failed.

A very small amount of sediment in the ponds and reservoirs has been derived from wave action along the shores and upstream faces of the dams. Many of the protective measures along the faces of the dams have deteriorated and the floats have become water logged and sunk so that no protection is now afforded against wave erosion. Trampling of cattle along the shores has tended to increase shore erosion to some extent, but on the whole, it appears that neither shore nor dam erosion has contributed substantial amounts of sediment.

APPLICATION OF DATA

Effects of Reservoir and Watershed Factors on Sedimentation[2]

As the purpose of this study was to determine the approximate rates of silting of all Government-owned ponds and reservoirs in the SD-LU-2 project area, based on representative surveys of a few,

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[2] Assistance and guidance in making the analyses described under this heading was given by Dr. A. E. Brandt, Research Specialist in Experimental Design and Analysis, Office of Research, Soil Conservation Service, Washington, D. C. This cooperation is gratefully acknowledged.

an analysis was made by multiple regression to determine the function of various reservoir, watershed and other factors which best explained the amount of sediment measured.[3] Factors tested included reservoir capacity, net drainage area, drainage density, age, and precipitation.

It was found that the total sediment accumulation in the ponds, based on the 18 representative surveys, could be expressed best by the formula:

$$S = 0.0573C + 0.0029A + 0.0125D + 0.2283T - 2.1194$$

where: S = Total sediment accumulation, in acre-feet

C = Capacity of the pond or reservoir, in acre-feet

A = Net drainage area, in acres

D = Drainage density, in feet per acre

T = Age, in years.

The above formula covers 93 percent of variability in sediment accumulation as expressed by the standard deviation. An equally good correlation is obtained when precipitation is substituted for age. In this case the formula developed was:

$$S = 0.0570C + 0.0029A + 0.0124D + 0.0176P - 2.6494$$

where: P = Total precipitation, in inches

Omission of drainage density from the calculations, and the use of age instead of precipitation, gave the formula:

$$S = 0.0522C + 0.0027A + 0.2681T - 1.7974,$$

which covers 89 percent of variability in sedimentation, as expressed by the standard deviation. Since the values of C, A and T were readily available from existing project data and since the correlation is still very good, this formula was used to compute the probable rate of silting of all the ponds and reservoirs on which no surveys were made. A nomograph, Figure 3, was constructed, using these factors, to facilitate estimation of total sedimentation in these ponds and reservoirs. It is believed that this nomograph also will be useful in adjacent areas where the watershed and reservoir factors are the same.

3/ For method used see "Correlation and Machine Calculation" by H. A. Wallace and George W. Snedecor, Iowa State College of Agriculture and Mechanic Arts, Official Publication, Vol. 30, No. 4, 71pp., June 24, 1931.

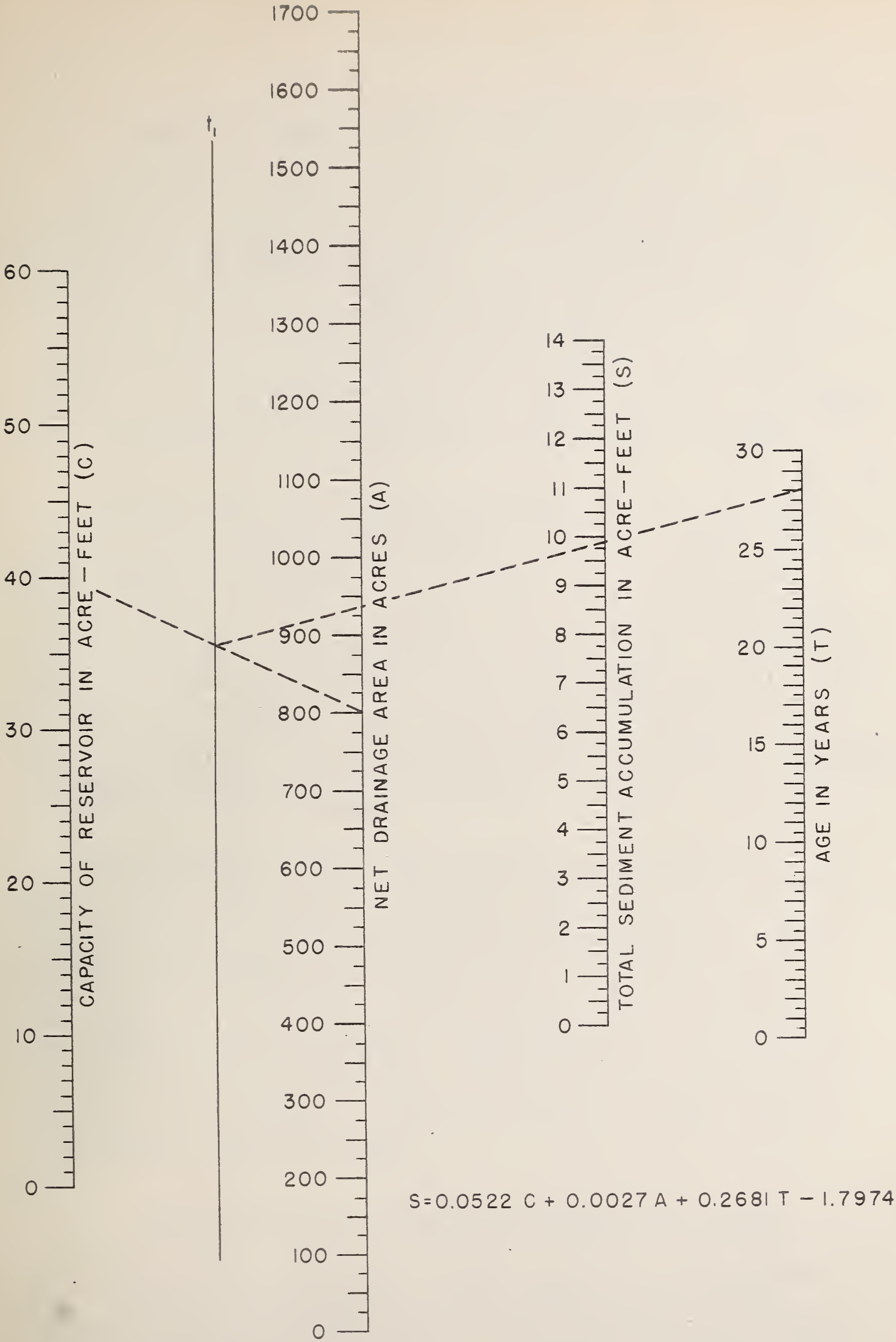

Figure 3.— Nomograph for estimating total sediment accumulation in stock water ponds and reservoirs on SD-LU-2 project, Pierre, S.Dak.

Adequacy of Data For Determining Long-Term Rates

The adequacy of the sedimentation data, based on only 8 or 9 years of record, for estimating long-term rates was tested by an analysis of precipitation records for this period as compared with the 53-year record at Pierre. In the analysis of sedimentation data by multiple regression methods a correlation giving 88 percent coverage of variability was obtained when both age and precipitation were omitted from the calculations. This might appear to indicate that these two factors are not important. However, total age must necessarily be one of the most important factors controlling the total accumulation of sediment in a reserboir. The apparent discrepancy may be outlined as follows:

Figure 4 shows that during the months of high erosion-producing precipitation, e.g. May, June and July, there was only one year during the period of sedimentation record, namely, 1938, in which rainfall during any one of these months was appreciably above normal. By this date all but four of the reservoirs had been constructed. It is not likely that any appreciable sedimentation took place in these reservoirs prior to May 1938 and probably very little before May 1941, by which time all of the reservoirs had been completed. As far as their sedimentation history is concerned, therefore, they are all nearly of the same age. Hence, the use or omission of precipitation and age in the multiple regression analysis does not, under these circumstances, show any appreciable effect on percentage of variability.

Precipitation in this area from March 1936 to May 1941 was considerably below normal, but it was considerably above normal for the period May 1941 to date of surveys, June 1945. Figure 5 shows that from the beginning of record to May 1941, the cumulative precipitation deficiency amounted to about 20 inches, or more than the amount that normally falls in an entire year. From May 1941 to June 1945, however, this cumulative deficiency was reduced to about 5 inches. Precipitation for the entire period, March 1936 to June 1945, was, therefore, slightly below normal and the estimated rates of sedimentation determined by this study are slightly on the conservative side with regard to the expected long-term rates.

Effect of Sedimentation on Dependable Water Supply

Damage from sedimentation becomes critical when sediment encroaches upon the dependable water supply or the storage needed during the grazing season, April to November, inclusive, to offset cummulative losses by evaporation, seepage and stock consumption. Any storage capacity in excess of the dependable capacity could be silted up before effects of sedimentation would become critical. An analysis, therefore, was made to determine the amount of excess storage capacity at each stock pond and reservoir in order to estimate how long it would take before silting encroached upon the dependable storage.

In the absence of previous studies in this area, the dependable water supply was arbitrarily chosen as one which will not fail more often then once in 5 years for the stock ponds and more than once in 15 years for the reservoirs. The dependable water supply was computed by the following formula:

$$C_d = RA + a(P-E-S)-U$$

where: C_d = Dependable storage capacity, in acre-feet

R = Runoff from net drainage area, in acre-feet per acre

A = Net drainage area, in acres

E = Evaporation from pond surface, in acre-feet per acre

P = Precipitation, in acre-feet per acre

a = Surface area of the pond, in acres

U = Amount of water used by livestock in acre-feet

S = Seepage from pond, in acre-feet per acre

Runoff studies made during the period 1941 to 1945 inclusive, on plots of 3 to 4 acres in size at Hastings, Nebraska, indicate that in this general area runoff from pasture land averages, during the period April to November, inclusive, about 6 percent of precipitation. From the 53-year record at Pierre, S. Dak., minimum total precipitation for the grazing season April to November was determined to be 9.6 inches for a 5-year recurrence interval and 7.0 inches for a 15-year recurrence interval. From these data the mean total runoff per acre of drainage for the eight-month period was calculated to be 0.048 acre-feet per acre of drainage for the 5-year recurrence interval and 0.035 acre-feet per acre of drainage for a 15-year recurrence interval.

The net drainage areas of the ponds and reservoirs were determined stereoscopically and planimetered directly from aerial photographs. Pond areas were determined by planimetering from detailed maps on the scale of 1 inch equals 100 feet.

Seepage losses were assumed to be 1.00 acre-feet per acre for the period of consideration based on a rate of seepage of 18 inches per year for Pierre soils.

Evaporation losses for the grazing season April to November were assumed to average 45.7 inches based on Meyer's charts.[4/]

4/ Adolph F. Meyer, "Evaporation from Lakes and Reservoirs". Minnesota Resources Commission, 58 pp., illus., June 1942.

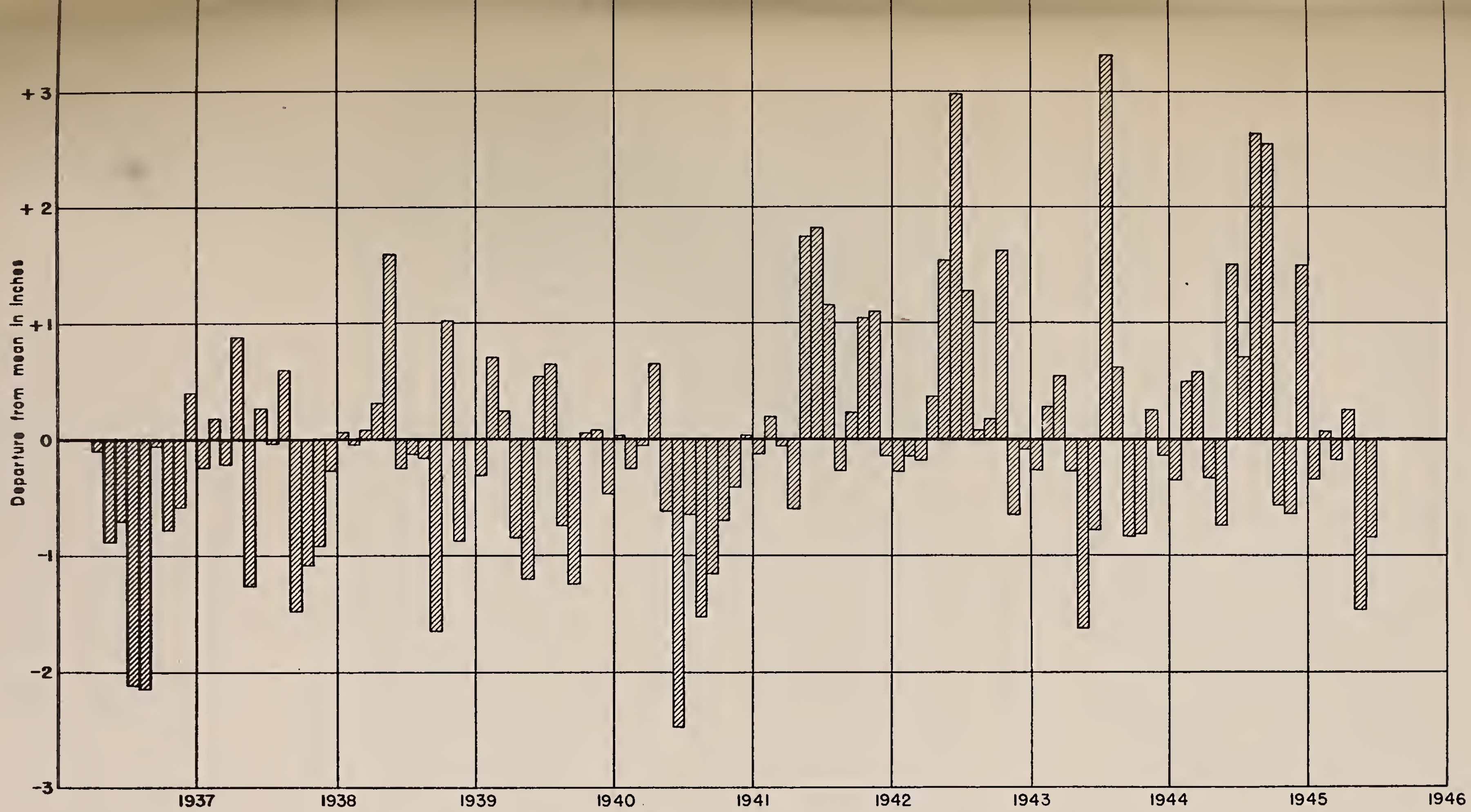

Figure 4. Departure of monthly precipitation from mean. March 1936—May 1945

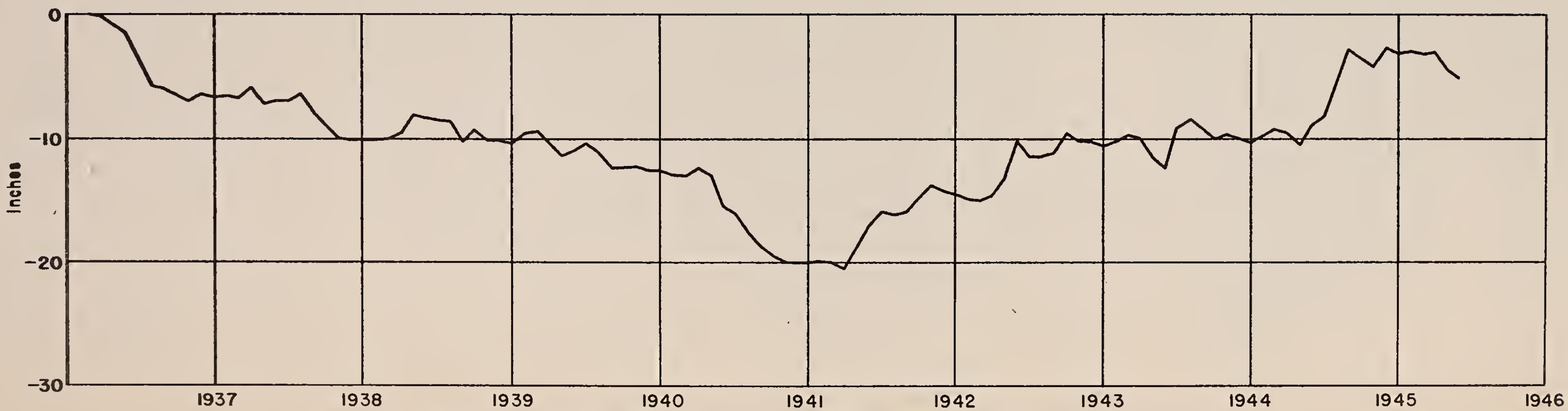

Figure 5. Accumulative difference curve of monthly precipitation, March 1936—May 1945

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and that this loss was active over 0.8 of the reservoir area. The factor 0.8 was used to compensate for decrease in the surface area of the ponds and reservoirs as the stage was lowered. Using these factors it was calculated that losses due to evaporation amount to 3.047 acre-feet per acre of surface area for the period under consideration. Stock consumption was estimated to be 1.00 acre-feet per pond or reservoir during the grazing season.

Using the above factors the dependable storage capacity, or the capacity needed to offset losses by seepage, evaporation and livestock consumption was calculated. The difference between the dependable storage capacity and the total capacity of a pond is the amount of storage in excess of the dependable storage. Knowing the approximate annual rate of silting from observed and calculated data the estimated life of the excess storage capacity was then determined. The results of these calculations are given in Table 2.

CONCLUSIONS

The annual rate of silting on the SD-LU-2 Project, Pierre, S. Dak., varies from 1.10 to 5.56 percent for stock ponds and from 0.93 to 2.94 percent for reservoirs. The estimated life, from date of construction, of storage in excess of the dependable storage varies from 7 to 73 years for stock ponds and from 30 to 90 years for reservoirs. Sediment is now encroaching upon the dependable storage capacity of only one Government-owned stock pond in the area. The average life of stock ponds in this area is considered to be about 25 years. Sediment will encroach upon the dependable storage capacity of only 2 of the 43 Government-owned ponds before the end of this span of years.

Serious channel erosion is taking place in the watersheds of several of the ponds and reservoirs particularly above 226-11. Since this is not taken into account in calculations for the ponds and reservoirs not surveyed, silting probably is proceeding in these reservoirs at a faster rate than indicated by the calculations. Such projects must be studied individually in the field to obtain a true value of the sedimentation damages. Because a sizable amount of sediment may be carried into the ponds from channel erosion, measures may be necessary at this time to protect them.

In general, it is believed that conservation measures such as reseeding, planting cropland to grass, controlling grazing, construction of check dams, etc., have had a decided influence in reducing the rate of silting not only of the Government-owned ponds and reservoirs but of all ponds and reservoirs in the project area. The control of channel erosion by check dams has not been too successful because of failure of the structures, mainly by side cutting. Most check dams that have failed should be replaced with more substantial structures, built with longer wing walls and in some cases with better protection against undercutting.

Table 2.--Summary of sedimentation data on reservoirs and stock ponds, SD-LU-2 Project, Pierre, S. Dak.

Project number	Location	Original capacity	Pond area	Total drainage area	Net drainage area 1/	Approximate date of completion	Age to July 1945	Estimated total sediment accumulation (Observed)	Estimated total sediment accumulation (Calculated) 2/	Estimated average annual sediment accumulation	Total depletion of storage	Annual depletion of storage	Estimated storage in excess of dependable storage requirements 3/	Estimated life of excess storage capacity 4/
		Acre-feet	Acres	Acres	Acres		Years	Acre-feet	Acre-feet	Acre-feet	Percent	Percent	Acre-feet	Years
226-1	SE-7-109-79	16.7	3.6	130	126	March 1936	9.3	1.509	1.91	0.162	9.04	0.97	7.6	47
226-2	NE-32-109-77	34.0	9.0	637	628	March 1936	9.3	4.179	4.17	0.449	12.29	1.32	23.8	53
226-3	NW-9-108-79	17.0	6.7	884	535	March 1935	9.3	---	3.03	0.326	17.82	1.92	11.5	35
226-4	NW-19-108-79	13.6	4.0	479	475	May 1936	9.2	3.678	2.66	0.400	27.04	2.94	13.6	34
226-5	SE-11-109-78	17.9	2.8	164	161	October 1936	8.7	---	1.90	0.218	10.61	1.22	12.8	59
226-6	NW-29-109-78	31.8	9.1	1635	1626	April 1936	9.3	6.733	6.75	0.724	21.17	2.28	31.8	44
226-7	SW-24-109-79	31.9	4.7	650	645	May 1936	9.2	---	4.08	0.443	12.79	1.39	31.9	72
226-8	SE-28-3-31	19.7	5.8	590	502	May 1936	9.2	---	3.05	0.332	15.48	1.69	16.2	49
226-9	NW-35-109-78	37.2	6.2	1028	1022	July 1936	9.0	---	5.32	0.591	14.30	1.59	37.2	63
226-10	NW-10-107-79	19.9	3.3	420	360	May 1936	9.2	---	2.68	0.291	13.47	1.46	19.9	68
226-11	SE-21-108-79	59.8	8.8	1192	1079	September 1936	8.8	---	6.60	0.750	11.04	1.25	59.8	80 5/
226-12	SW-11-107-78	33.0	7.2	720	713	August 1936	8.9	---	4.24	0.476	12.85	1.44	32.0	67
226-13	SE-29-3-31	9.1	1.7	106	104	October 1936	8.7	0.739	1.29	0.085	8.12	0.93	5.9	69
226-14	NW-29-2-31	216.7	33.2	2990	2239	September 1936	8.8	---	17.92	2.036	8.27	0.94	179.1	88
226-15	NE-15-108-78	87.8	23.7	1810	1786	August 1936	8.9	---	9.99	1.122	11.38	1.28	67.2	60
226-16	SE-30-108-79	10.2	2.5	222	156	September 1936	8.8	---	1.52	0.173	14.90	1.70	6.0	35
226-17	NE-18-107-78	25.5	5.3	576	508	November 1936	8.7	---	3.24	0.372	12.71	1.46	23.9	64
226-18	SW-26-109-79	13.5	4.3	960	388	September 1936	8.8	---	2.31	0.263	17.11	1.95	11.2	43
226-20	NW-29-107-78	73.2	15.1	1952	1361	October 1936	8.7	---	8.03	0.923	10.97	1.26	67.5	73
226-21	NE-24-108-79	28.9	6.8	157	150	October 1936	8.7	2.826	2.45	0.325	9.78	1.12	9.6	30
226-22	SW-2-109-79	9.2	2.5	329	327	November 1936	8.7	0.888	1.90	0.102	9.65	1.11	9.2	90
226-23	NW-17-109-77	39.3	6.9	1628	822	November 1936	8.7	---	4.81	0.553	12.24	1.41	39.3	71
226-24	SW-2-108-79	98.0	22.4	2370	2348	November 1936	8.7	---	11.99	1.378	12.23	1.41	98.0	71
226-25	SW-8-106-78	9.3	2.1	94	92	November 1937	7.7	0.883	1.00	0.115	9.49	1.24	4.2	37
226-26	NE-8-2-31	150.0	15.7	2886	2411	June 1937	8.1	---	14.71	1.816	9.81	1.21	150.0	83
226-28	NW-6-107-78	30.3	4.3	472	457	December 1936	8.6	---	3.32	0.386	10.96	1.27	30.3	78
226-30	SE-30-109-77	100.0	20.0	2300	1942	March 1937	8.3	---	10.89	1.312	10.89	1.31	97.7	74
226-31	NE-26-108-79	13.9	3.1	144	141	March 1937	8.3	1.565	1.53	0.189	11.26	1.36	7.1	38
226-32	NE-9-107-78	14.1	3.2	305	302	March 1937	8.3	1.991	1.98	0.240	14.12	1.70	12.5	52
226-34	NW-21-1-31	44.3	7.7	782	774	June 1937	8.1	4.336	4.78	0.535	9.79	1.21	43.7	82
226-35	NW-32-107-79	18.4	4.3	325	321	May 1938	7.2	2.282	1.96	0.317	12.40	1.72	13.8	44
226-36-B	SW-2-107-78	19.6	2.1	747	745	February 1938	7.4	---	3.22	0.435	16.43	2.22	19.6	45
243-1	NE-17-107-79	2.7	0.83	69	68	November 1937	7.7	0.661	0.59	0.086	24.48	3.19	2.3	27
243-2	NW-27-107-79	5.2	1.9	86	84	November 1937	7.7	2.224	0.77	0.289	42.77	5.56	2.0	7
243-3	NW-13-2-30	4.0	0.75	179	178	November 1937	7.7	---	0.96	0.125	24.00	3.13	4.0	32
243-4	NE-11-107-79	3.1	0.62	165	164	November 1937	7.7	---	0.87	0.113	28.07	3.65	3.1	27
243-5	NW-21-107-78	2.6	0.67	46	45	November 1937	7.7	0.380	0.52	0.049	14.62	1.88	1.5	31
243-6	NW-9-1-31	3.2	0.85	75	74	November 1937	7.7	0.422	0.63	0.055	13.19	1.72	0.6	11
243-7	SW-35-108-78	5.0	0.92	245	244	March 1938	7.3	---	1.08	0.148	21.60	2.96	5.0	34
243-10	NE-7-106-79	3.7	1.2	341	340	June 1938	7.1	0.835	1.22	0.118	22.57	3.19	3.7	31
243-11	SW-33-1-31	4.5	1.3	217	216	July 1938	7.0	0.633	0.90	0.090	14.07	2.00	4.5	50
243-12	SW-5-109-77	8.2	0.57	27	26	March 1938	7.3	---	0.66	0.090	8.05	1.10	6.6	73
243-14	SE-7-107-79	13.0	4.02 6/	790	786	November 1938	6.7	---	2.80	0.418	21.54	3.22	13.0	31

1/ Excludes reservoir areas and drainage areas controlled by stock ponds in watershed.
2/ Calculated by formula $S = 0.0522C + 0.0027A + 0.2681T - 1.7974$.
3/ 15-year recurrence interval for reservoirs, and 5-year recurrence interval for stock ponds.
4/ Years from date of construction.
5/ Does not take into account serious channel erosion in the watershed which will substantially reduce the estimated life.
6/ Estimated area.

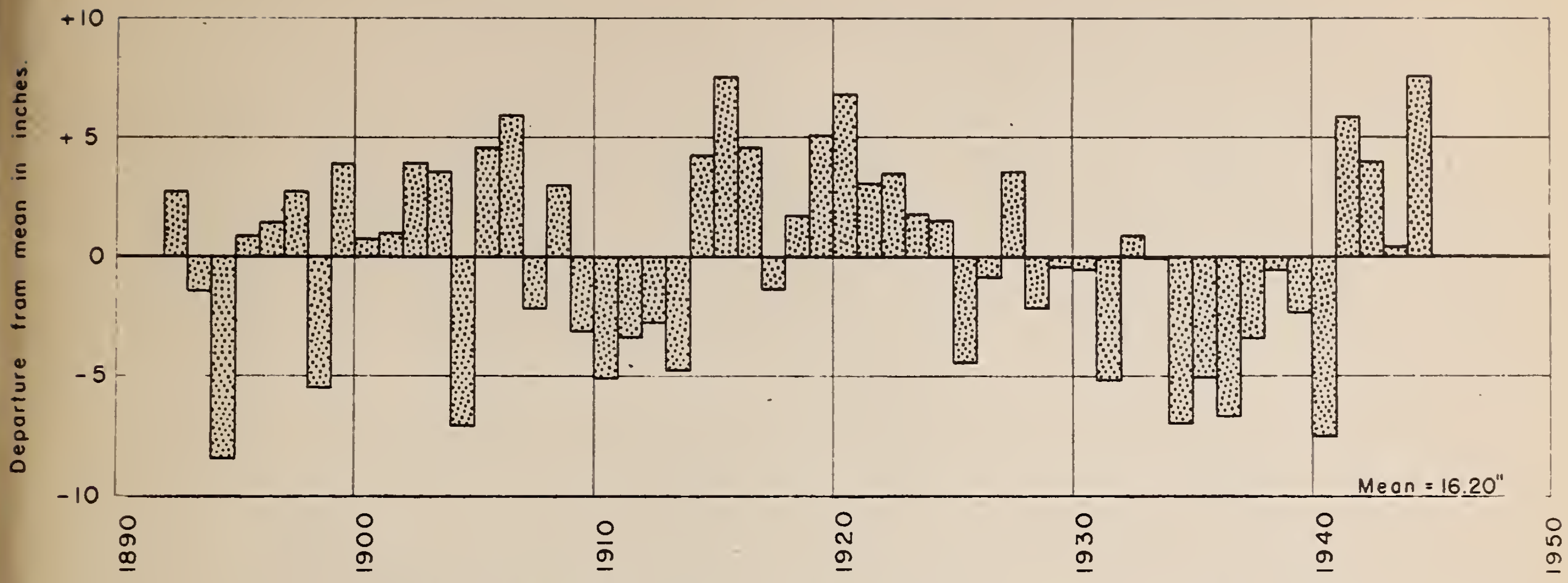

Figure 1.— Departure of annual precipitation from mean at Pierre, S. Dak.

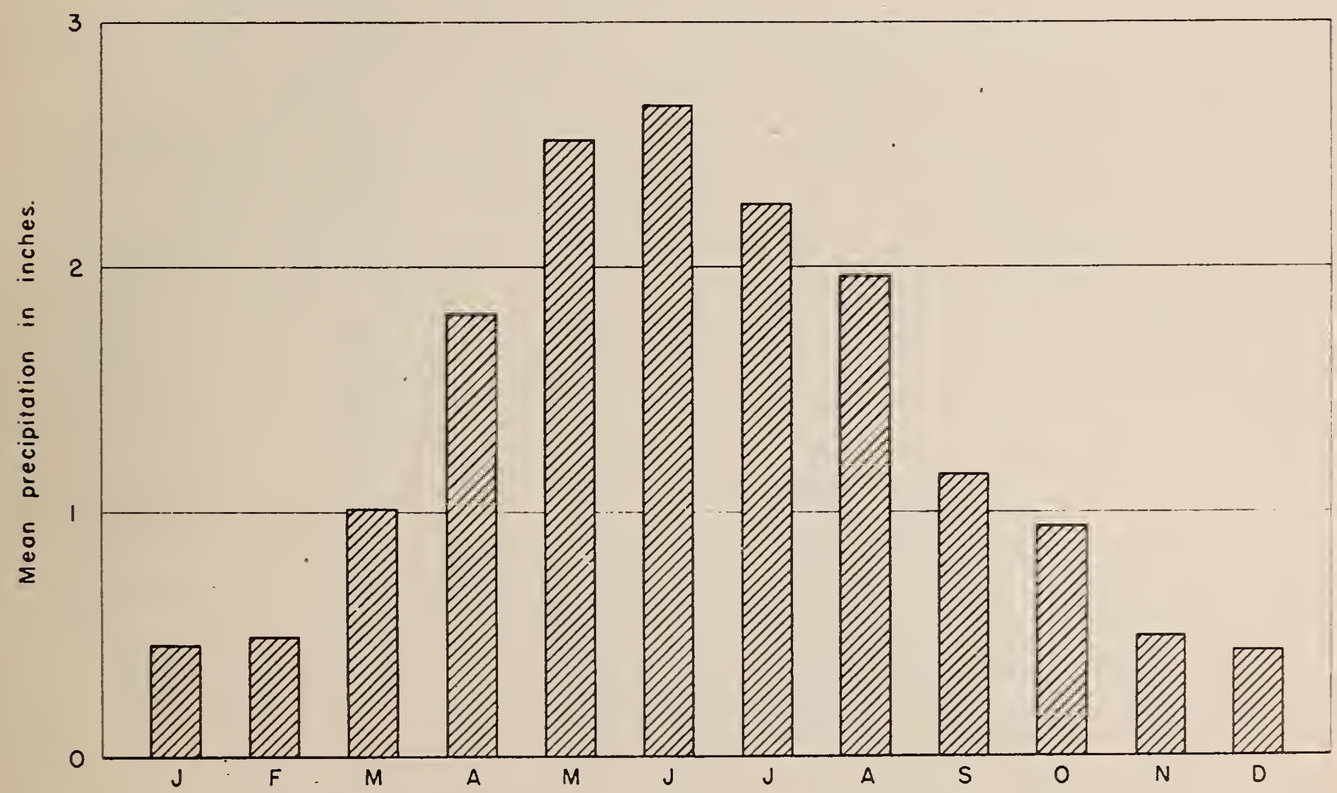

Figure 2.— Seasonal distribution of precipitation, Pierre, S. Dak.
Compiled from 53 - year record, 1891 to 1944

O-4253

0-4256

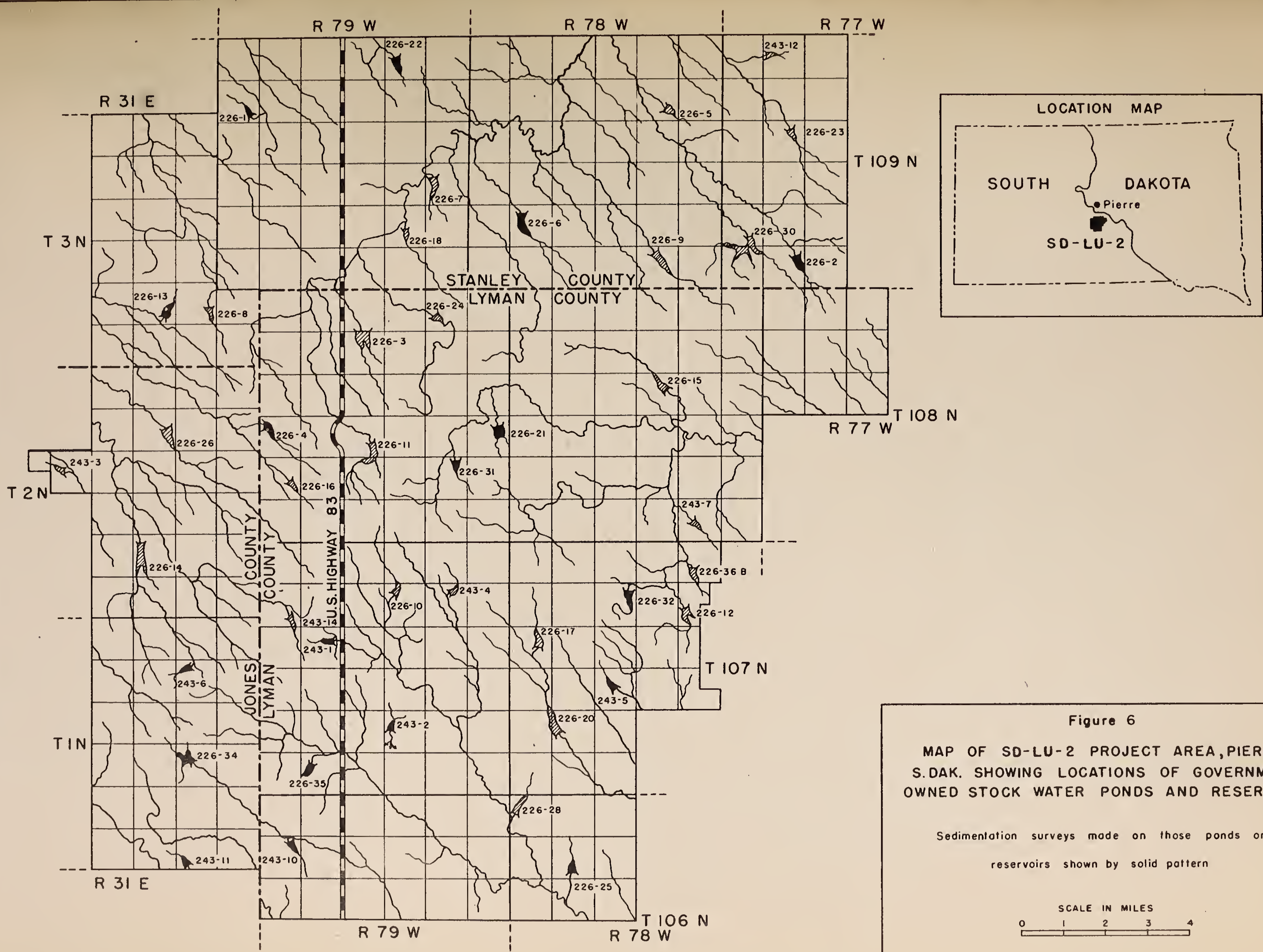

Figure 6

MAP OF SD-LU-2 PROJECT AREA, PIERRE, S. DAK. SHOWING LOCATIONS OF GOVERNMENT-OWNED STOCK WATER PONDS AND RESERVOIRS

Sedimentation surveys made on those ponds and reservoirs shown by solid pattern

SCALE IN MILES

0 1 2 3 4